

RADIO LINK PROTOCOL ENHANCEMENTS TO REDUCE SETUP TIME FOR DATA CALLS

Claim of Priority under 35 U.S.C. §120

[1001] The present Application for Patent is a Continuation application and claims priority to Patent Application No. 09/437,417 entitled "RADIO LINK PROTOCOL ENHANCEMENTS TO REDUCE SETUP TIME FOR DATA CALLS" filed November 10, 1999, now allowed, and assigned to the assignee hereof and hereby expressly incorporated by reference herein.

BACKGROUND

I. Field of the Invention

[1002] The current invention relates to wireless communications. More particularly, the present invention relates to an improved method and system that requires decreased setup time in establishing a radio link protocol (RLP) data call.

II. Description of the Related Art

[1003] The use of code division multiple access (CDMA) modulation techniques is one of several techniques for facilitating communications in which a large number of system users are present. Other multiple access communication system techniques, such as time division multiple access (TDMA), frequency division multiple access (FDMA) and AM modulation schemes such as amplitude companded single sideband (ACSSB) are known in the art. These techniques have been standardized to facilitate interoperability between equipment manufactured by different companies. Code division multiple access communications systems have been standardized in the United States in Telecommunications Industry Association TIA/EIA/IS-95-B, entitled "MOBILE STATION-BASE STATION COMPATIBILITY STANDARD FOR DUAL-MODE WIDEBAND SPREAD SPECTRUM CELLULAR SYSTEMS", incorporated by reference herein, and hereinafter referred to as IS-95. In addition, a new standard for Code division multiple access communications

systems has been proposed in the United States in Telecommunications Industry Association PN-4431 to be published as TIA/EIA/IS-2000-5, entitled "UPPER LAYER (LAYER 3) SIGNALING STANDARD FOR cdma2000 SPREAD SPECTRUM SYSTEMS", dated July 11, 1999, incorporated by reference herein, and hereinafter referred to as IS-2000.

[1004] The International Telecommunications Union recently requested the submission of proposed methods for providing high rate data and high-quality speech services over wireless communication channels. A first of these proposals was issued by the Telecommunications Industry Association, entitled "The cdma2000 ITU-R RTT Candidate Submission." A second of these proposals was issued by the European Telecommunications Standards Institute (ETSI), entitled "The ETSI UMTS Terrestrial Radio Access (UTRA) ITU-R RTT Candidate Submission", also known as "wideband CDMA" and hereinafter referred to as W-CDMA. A third proposal was submitted by U.S. TG 8/1 entitled "The UWC-136 Candidate Submission", hereinafter referred to as EDGE. The content of these submissions is public record and is well known in the art.

[1005] IS-95 was originally optimized for transmission of variable-rate voice frames. In order to support two-way voice communications, as typified in wireless phone applications, it is desirable that a communication system provides fairly constant and minimal data delay. For this reason, IS-95 systems are designed with powerful forward error correction (FEC) protocols and vocoders which are designed to respond gracefully to voice frame errors. Error control protocols which require frame retransmission procedures add unacceptable delays to voice transmission, so are not designed into the IS-95 specification.

[1006] The optimizations which make the standalone IS-95 specification ideal for voice applications make it difficult to use for packet data applications. In many non-voice applications, such as the transmission of Internet protocol (IP) data, the delay requirements of the communication system are much less stringent than in voice applications. In the Transmission Control Protocol (TCP), probably the most prevalent of protocols used in an IP network, virtually infinite transmission delays are allowed in order to guarantee error-free transmission. TCP uses retransmissions of IP datagrams, as IP packets are commonly called, to provide this transport reliability.

[1007] IP datagrams are generally too large to fit into a single IS-95 frame. Even after dividing an IP datagram into segments small enough to fit into a series of IS-95 frames, an entire series of IS-95 frames would have to be received without error for the single IP datagram to be useful to TCP. The frame error rate typical of an IS-95 system make the probability of error-free reception of all segments of a single datagram very low.

[1008] As described in IS-95, alternative service options enable the transmission of other types of data may in lieu of voice frames. The TIA/EIA/IS-707-A, entitled "DATA SERVICE OPTIONS FOR SPREAD SPECTRUM SYSTEMS", hereafter referred to as IS-707, describes procedures used in the transmission of packet data in an IS-95 system.

[1009] Radio Link Protocol (RLP) is described in TIA/EIA/IS-707-A.8, entitled "DATA SERVICE OPTIONS FOR SPREAD SPECTRUM SYSTEMS: RADIO LINK PROTOCOL TYPE 2", hereinafter referred to as RLP2, and incorporated herein by reference. RLP2 incorporates an error control protocol with frame retransmission procedures over the IS-95 frame layer. RLP is of a class of error control protocols known NAK-based ARQ protocols, which are well known in the art. The IS-707 RLP facilitates the transmission of a byte-stream, rather than a series of voice frames, through an IS-95 communication system.

[1010] Several protocol layers typically reside above the RLP layer. IP datagrams, for example, are typically converted into a Point-To-Point Protocol (PPP) byte stream before being presented as a byte stream to the RLP protocol layer. As the RLP layer ignores the protocol and framing of higher protocol layers, the stream of data transported by RLP is said to be a "featureless byte stream".

[1011] RLP was originally designed to satisfy the requirements of sending large frames through an IS-95 channel. For example, if an IP datagram of 500 bytes were to be simply sent in IS-95 frames carrying 20 bytes each, the IP datagram would fill 25 consecutive IS-95 frames. Without some kind of error control layer, all 25 of these frames would have to be received without error in order for the IP datagram to be useful to higher protocol layers. On an IS-95 channel having a 1% frame error rate, the effective error rate of the IP datagram delivery would be $(1 - (0.99)^{25})$, or 22%. This is a very high error rate compared to most networks used to carry Internet Protocol traffic. RLP was designed as a

link layer protocol which would decrease the error rate of IP traffic to be comparable to the error rate typical of a 10Base2 ethernet channel.

[1012] RLP is a negative acknowledgment (NAK) based protocol in which NAK frames are sent to prompt retransmission of data frames lost because of communication errors. The timing of NAK frame transmission is based on estimates of round-trip time (RTT) determined at the start of an RLP session. RTT determination in existing version of RLP requires a 3-way handshake in which both sides transmit specific frame types based on the frame types received. No data is sent by either side until the completion of the 3-way handshake. This 3-way handshake consumes time that could otherwise be used to transmit data.

[1013] In a typical data services configuration, a laptop computer is connected to a wireless modem that communicates with a network over an RLP connection. In a typical laptop computer application like browsing an Internet web page, the computer does not continuously exchange data with the network. Instead, the computer typically sends a short request for data containing the address of a web page. The wireless modem responds by establishing an RLP session with the local base station, and relays the request through the base station to the network. Through this RLP session, the wireless modem then receives the requested data (such as the contents of a web page), and displays the data for the user. While the user is reading the displayed data, no data is exchanged between the wireless modem and the base station or network.

[1014] In order to allow the most efficient use of wireless spectrum, a typical network employs "activity timers" that tear down an RLP session after a predetermined period of link inactivity. If this happens before the laptop computer attempts to send more data through the wireless modem, then another RLP session is established to service the new data. The re-establishing of a new RLP session causes additional delay in exchanging data with the network, which can be characterized by "sluggishness" of the laptop computer.

[1015] Bringing up a new RLP session to send new data will always take longer than sending the new data over an already-existing RLP session. Existing versions of RLP require the performance of a 3-way handshake to establish an RLP session. It is therefore highly desirable to minimize the

overhead required to establish an RLP session, including minimizing or eliminating the delay inherent in the 3-way handshake.

SUMMARY

[1016] The present invention may be used to allow transmission of RLP data without requiring the completion of a 3-way handshake. The present invention is applicable to any communication system employing transmission of a byte stream over a wireless channel. The present invention is applicable to systems such as cdma2000, W-CDMA, and EDGE, wherein a byte stream may be carried within over-the-air frames specified for use by the wireless communication system.

[1017] The present invention includes methods of negotiating an initial RTT estimate to be used for an RLP call. The initial RTT estimate, along with other RLP parameters such as NAK scheme and encryption parameters, are negotiated during service negotiation. At the conclusion of service negotiation, both sides of the RLP communication link are armed with an initial RTT estimate and may begin sending RLP data frames without performing the 3-way handshake.

[1018] The present invention includes methods for the base station to determine and update initial RTT estimate values proposed during service negotiations. The present invention also includes methods by which both sides of an RLP communication link can dynamically update and refine the initial RTT estimates specified during service negotiation.

BRIEF DESCRIPTION OF THE DRAWINGS

[1019] The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

[1020] **FIG. 1** is a diagram of a data communications system configured in accordance with an embodiment of the invention.

[1021] **FIG. 2** is a diagram showing the flow of messages used to establish an RTT estimate using an RLP 3-way handshake.

[1022] **FIG. 3a** is a diagram showing the flow of messages used to establish a subscriber station originated RLP call having an RTT estimate in accordance with an embodiment of the invention.

[1023] **FIG. 3b** is a diagram showing the flow of messages used to establish a base station originated RLP call having an RTT estimate in accordance with an embodiment of the invention.

[1024] **FIG. 4a** is a flowchart of the steps taken by a subscriber station to initialize and use an RLP link in accordance with an embodiment of the invention.

[1025] **FIG. 4b** is a flowchart of the steps taken by a base station to initialize and use an RLP link in accordance with an embodiment of the invention.

[1026] **FIG. 5** is a flowchart of the steps used to update RTT estimates during an RLP session in accordance with an embodiment of the invention.

[1027] **FIG. 6** is a block diagram of an apparatus used to establish and use an RLP link through a CDMA wireless communication channel in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

[1028] **FIG. 1** is a diagram of a data communications system configured in accordance with an embodiment of the invention. As shown, subscriber station **102** communicates with network **108** through wireless communication channel **106** and base station **104**.

[1029] Subscriber station **102** and base station **104** establish a radio link protocol (RLP) communication link to convey data byte streams through wireless communication channel **106**. The data bytes exchanged between subscriber station **102** and network **108** through base station **104** may be Internet Protocol (IP) datagrams converted into a byte stream using such conversion protocols as point-to-point protocol (PPP). Both IP and PPP protocols are well known in the art.

[1030] Before any data can be exchanged between subscriber station **102** and base station **104**, the RLP link between the two must be established. Establishing an RLP link includes establishing a round-trip time (RTT) to be used by both subscriber station **102** and base station **104** for negative

acknowledgment (NAK) timing. In an exemplary embodiment of the present invention, subscriber station **102** sends base station **104** a Service Request Message specifying that subscriber station **102** can accept an initial RTT estimate sent in a Service Response Message from base station **104**. Upon receiving this Service Request Message, base station **104** sends subscriber station **102** a Service Response Message that includes an initial RTT estimate to be used by subscriber station **102**. After base station **104** provides an initial RTT estimate to subscriber station **102**, there is no need to perform a time-consuming 3-way handshake. Thereafter, when either side transmits a NAK frame, it uses the delay between transmission of the NAK frame and receipt of a corresponding retransmit frame to update its RTT estimate for use in the ongoing RLP communication link.

[1031] FIG. 2 shows how an initial RTT estimate is established in conventional RLP communication links using the 3-way handshake. Subscriber station **102** transmits SYNC frames **202**, SYNC/ACK frames **204**, ACK frames **206** and data frames **208** to base station **104** on the reverse link. Base station **104**, in turn, transmits SYNC frames **220**, SYNC/ACK frames **222**, ACK frames **224** and data frames **226** to subscriber station **102** on the forward link. In the example shown, round trip time (RTT) **230** is 8 frames long. The entire synchronization period **232** of generating a first RTT estimate is 12 frames long, or one and one half times as long as RTT.

[1032] At the time of starting RLP synchronization **240**, both sides transmit SYNC frames **202** and **220**. As shown, subscriber station **102** transmits one SYNC frame in every frame period. Base station **104** also begins the synchronization process by transmitting one SYNC frame **220** in every frame period.

[1033] At time **242**, after half of first RTT period **230** and after subscriber station **102** has sent four SYNC frames **202a** to **202d**, subscriber station **102** receives the first SYNC frame **220** transmitted by base station **104**. Upon receiving this first SYNC frame **220**, subscriber station stops transmitting SYNC frames and instead transmits one SYNC/ACK frame **204** every frame period. Also at time **242**, base station **104** receives the first SYNC frame **202a** transmitted by subscriber station **102**. Upon receiving this first SYNC frame

202a, base station **104** stops transmitting SYNC frames and instead transmits one SYNC/ACK frame **222** every frame period.

[1034] At time **244**, subscriber station **102** receives the first SYNC/ACK frame **222** transmitted by base station **104**. Upon receiving this first SYNC/ACK frame **222**, subscriber station stops transmitting SYNC/ACK frames and instead transmits one ACK frame **206** every frame period. Also at time **244**, base station **104** receives the first SYNC/ACK frame **204** transmitted by subscriber station **102**. Upon receiving this first SYNC/ACK frame **204**, base station **104** stops transmitting SYNC/ACK frames and instead transmits one ACK frame **224** every frame period.

[1035] At time **246**, subscriber station **102** receives the first ACK frame **224** transmitted by base station **104**. Upon receiving this first ACK frame **224**, subscriber station stops transmitting ACK frames and can begin sending Data frames **208** every frame period. Also at time **246**, base station **104** receives the first ACK frame **206** transmitted by subscriber station **102**. Upon receiving this first ACK frame **206**, base station **104** stops transmitting ACK frames and can begin sending Data frames **226**.

[1036] The period between time **240** and time **246** is one and one half times as long as the RTT **232** used for timing of subsequent NAK frames. In other words, the time between transmitting the first SYNC frames **240** and the transmitting the first data frames **246** is one and one half times as long as RTT **232**. If RTT **230** is 8 frames as shown, then the time required to perform the 3-way handshake **232** is 12 frames.

[1037] If any SYNC, SYNC/ACK or ACK frames are lost to communication errors during the 3-way handshake, this synchronization time can be longer. Additionally, such communication errors can cause the resultant RTT estimate to be longer than the actual RTT of the RLP link. An RTT estimate that is longer than the actual RTT of the RLP link leads to undesirable delays in sending additional NAK frames when a previous NAK frame is lost (again, due to communication errors). Such delays can cause sluggishness in the protocol and can degrade the throughput of the RLP link.

[1038] **FIG. 3a** is a diagram of an improved message flow used to establish an RTT estimate for a subscriber station originated RLP call in accordance with an embodiment of the invention. Instead of performing a 3-way handshake,

base station **104** sends subscriber station **102** an initial RTT estimate to use in an over-the-air message prior to establishing the RLP link.

[1039] In the exemplary embodiment, subscriber station **102** begins by transmitting a Service Request Message **302** to base station **104**. In the preferred embodiment of the invention, this message includes indications that subscriber station **102** supports receiving an initial RTT from base station **104** without a 3-way handshake. In the preferred embodiment, Service Request Message **302** optionally includes additional parameters such as specifying one or more NAK schemes supported by subscriber station **102**. Service Request Message **302** also optionally includes encryption parameters for the RLP communication link.

[1040] A NAK scheme is characterized by the number of NAK frames sent after each expiration of a NAK timer when a corresponding retransmit frame was not received. An example of a NAK scheme is a 1,2,3 NAK scheme wherein first one NAK is sent. If the NAK timer associated with that first "round" of NAK's expires without the reception of a corresponding retransmit frame, then another round of NAK's consisting of two NAK frames is transmitted. If the NAK timer associated with the second round of NAK's expires without receiving at least one corresponding retransmit frame, then a third round of three NAK's is transmitted. Other possible NAK schemes include a five-round 1,1,1,1,1 scheme, a two-round 1,2 scheme. Alternately, Service Request Message **302** may indicate a no-NAK scheme appropriate for a synchronous RLP protocol, as is well known in the art.

[1041] Upon receiving Service Request Message **302** indicating no 3-way handshake, base station **104** transmits Service Response Message **304** containing any additional or proposed modifications to link parameters. Upon receiving Service Response Message **304**, subscriber station **102** transmits a second Service Request Message **306** indicating acceptance or rejection of the parameters proposed in Service Response Message **304**. Upon receiving Service Request Message **306**, base station **104** transmits Service Connect Message **308** indicating the final link parameters to be used. Service Response Messages **304** and **308** and Service Connect Message **308** may all additionally indicate NAK schemes or encryption parameters as discussed above.

[1042] After transmitting Service Connect Message **308**, base station **104** may immediately begin to transmit Data frames **310** in subsequent frame periods. Upon receiving Service Connect Message **308**, subscriber station **102** may begin immediately transmitting Data frames **312** to base station **104**. As discussed in IS-2000, transmission of Data frames **310** and **312** may also be delayed until an "action time" specified in one or more of the previous messages, or until a Service Connect Complete Message (not shown) is received by one or both sides. One skilled in the art will appreciate that an additional "action time" parameter or a Service Connect Complete Message may be employed without departing from the present invention.

[1043] Upon receiving the first Service Request Message **302**, base station **104** may also elect to send Service Connect Message **308** immediately. This short cut makes it unnecessary to spend time transmitting Service Response Message **304** and Service Request Message **306**. Such a short cut only works when the parameters proposed by base station **104** in Service Connect Message **308** are supported by subscriber station **102** and are appropriate for the type of data to be exchanged over the RLP communication link.

[1044] In the preferred embodiment, if no specific NAK scheme is indicated in the various messages, both sides assume a predetermined default NAK scheme, for example the 1,2,3 scheme described above. Allowing such a predetermined default NAK scheme preserves message space and bandwidth during service negotiation.

[1045] In the preferred embodiment, the format of each of the messages (Service Request Message **302**, Service Response Messages **304** and **308** and Service Connect Message **308**) is as described in the aforementioned IS-2000 specification. In the preferred embodiment, each of the messages includes an RLP_BLOB section, which is a new form of BLOB adapted for RLP negotiation purposes. BLOB in IS-2000 is short for "block of bits." In the preferred embodiment, the RLP_BLOB includes the initial RTT estimate to be used and the NAK scheme. An exemplary format for RLP_BLOB is described in **Table 1** below.

Table 1

Field	Length (bits)
RLP_BLOB_ID	3
RTT	4
NAK_ROUNDS_FWD	3
NAK_ROUNDS_REV	3
NAK_ROUNDS_FWD occurrences of the following:	
NAK_PER_ROUND_FWD	3
NAK_ROUNDS_REV occurrences of the following:	
NAK_PER_ROUND_REV	3

[1046] In **Table 1**, the RLP_BLOB_ID field indicates a version number of the RLP_BLOB format used to interpret the rest of the contents of the RLP_BLOB section. RTT is the initial RTT value to be used in the call. NAK_ROUNDS_FWD indicates the number of NAK rounds to be used for forward link RLP transmissions. NAK_ROUNDS_REV indicates the number of NAK rounds to be used for reverse link RLP transmissions. As indicated, the NAK_ROUNDS_REV field is followed by a number of NAK_PER_ROUND_FWD fields corresponding to the value in the NAK_ROUNDS_FWD field. The last of the NAK_PER_ROUND_FWD fields is followed by a number of NAK_PER_ROUND_REV fields corresponding to the value in the NAK_ROUNDS_REV field. If the NAK_ROUNDS_FWD field has a value of zero, then the NAK_PER_ROUND_REV fields (if any) will immediately follow the NAK_ROUNDS_REV field.

[1047] For example, in a message indicating that a 1,2,3 NAK scheme on both forward and reverse links, the RLP_BLOB field has a NAK_ROUNDS_FWD value of 3 and a NAK_ROUNDS_REV value of 3. The NAK_ROUNDS_REV field is followed by three NAK_PER_ROUND_FWD fields having values 1, 2 and 3 respectively. The last NAK_PER_ROUND_FWD field is followed by three NAK_PER_ROUND_REV fields having values 1, 2 and 3 respectively.

[1048] In addition to using the message types described above, initial RTT times, NAK schemes and encryption parameters may be negotiated using

RLP_BLOB sections in other types of messages. Such message types include but are not limited to the General Handoff Direction Message (GHDM) and Universal Handoff Direction Message (UHDM) described in the aforementioned IS-2000.

[1049] In the preferred embodiment, any of the previously discussed messages that omit the RLP_BLOB section is interpreted as indicating the performance of a 3-way handshake. The NAK scheme may then be a predetermined default, or may be negotiated during the 3-way handshake.

[1050] In an alternate embodiment, base station **104** may further reduce the number of messages required to specify RTT and NAK schemes for an RLP call. By keeping track of the options supported in previous RLP calls to each subscriber station, base station **104** can begin a call by transmitting a Service Connect Message **308** specifying the RLP parameters to be used. After sending Service Connect Message **308**, and without receiving a Service Request Message **302** or Service Response Message from subscriber station **102**, base station **104** begins transmitting user data.

[1051] Several methods may be employed by base station **104** to determine the initial RTT estimate to specify to a subscriber station at the start of an RLP call. In a preferred embodiment, base station **104** obtains the initial RTT estimate by adding a predetermined guard time to the average of RTT values computed during 3-way handshakes for previous calls. In an alternate embodiment, the initial RTT estimate is configured in base station **104** by a wireless service operator.

[1052] **FIG. 3b** is a diagram showing a variation of the improved message flow used to establish an RTT estimate for a base station originated RLP call in accordance with an embodiment of the invention. In contrast to a subscriber station originated call, in a base station originated call Service Request Message **342** is transmitted by base station **104** and Service Response Message **344** is transmitted by subscriber station **102**. Service Connect Message **308** has the same format and content discussed above. As shown, base station **104** begins transmitting forward RLP data frames **310** immediately after Service Connect Message **308**. Upon receiving Service Connect Message **308**, subscriber station **102** begins transmitting reverse RLP data frames **312**.

[1053] In the exemplary embodiment, Service Request Message **342** includes a proposal that both sides of the link use an initial RTT estimate instead of using the 3-way handshake. As shown, subscriber station **102** accepts the proposal in Service Response Message **344**, and the 3-way handshake is not performed between Service Connect Message **308** and RLP data frames **310** and **312**.

[1054] All the same RLP parameters described in conjunction with subscriber station originated RLP calls can be negotiated in the messages shown for a base station originated RLP call. For example, Service Request Message **342** may include a proposed NAK scheme, which is accepted in Service Response Message **344**.

[1055] **FIG. 4a** is a flowchart of the steps taken by a subscriber station to initialize and use an RLP communication link in accordance with an embodiment of the invention. The steps are shown for a subscriber station originated RLP call, such as that shown in **FIG. 3a**, and for a base station originated RLP call, such as that shown in **FIG. 3b**.

[1056] In a subscriber station originated RLP call **400**, the subscriber station initiates service negotiations by sending a first Service Request Message **402** indicating the subscriber station's ability to negotiate an initial RTT estimate during service negotiation or other proposed RLP parameters. The subscriber station then receives and decodes the response **404** from the base station. The type of the response received is evaluated **406** to decide whether to negotiate further RLP parameters. If the message received was a Service Response Message, perhaps proposing changes to the RLP parameters previously sent, then the subscriber station sends another Service Request Message **402**. The new Service Request Message contains a set of parameters that either match or modify the new RLP parameters proposed by the base station. The subscriber station then waits until it receives another response **404** to the most recent Service Request Message.

[1057] Eventually, the response type is found at step **406** to be a Service Connect Message containing the RLP parameters to be used. The Service Connect Message is evaluated at step **408** to determine whether the Service Connect Message indicates performance of a 3-way handshake. If the Service Connect Message indicates performance of a 3-way handshake, then the 3-way

handshake is performed **410** prior to starting to send user data **412**. If the Service Connect Message indicates that a the 3-way handshake is not necessary and instead specifies an initial RTT estimate to be used, then the subscriber station may immediately begin to send user data **412**.

[1058] As mentioned previously, the Service Connect Message may indicate that a 3-way handshake is not necessary, but not include initial RTT estimate. In this case, the subscriber station will use a predetermined default initial RTT estimate.

[1059] In a base station originated RLP call **420**, the subscriber station receives and decodes a first Service Request Message **422** from the base station. This Service Request Message might indicate that the base station supports specifying an initial RTT estimate during service negotiation. The subscriber station responds by sending a Service Response Message **424**, indicating that the subscriber also supports using an initial RTT estimate received during service negotiation. The subscriber station then receives and decodes the next response message **426** sent by the base station. The type of response is evaluated **428**. The response may be another Service Request Message, for example indicating a proposal for a particular NAK scheme or other additional RLP parameters. The subscriber station then sends another Service Response Message **424** indicating acceptance or rejection of the additional RLP parameters. When a Service Connect Message is received, then processing passed from step **428** to step **408** previously described.

[1060] **FIG. 4b** is a flowchart of the steps taken by a base station to initialize and use an RLP communication link in accordance with an embodiment of the invention. The steps are shown for a subscriber station originated RLP call, such as that shown in **FIG. 3a**, and for a base station originated RLP call, such as that shown in **FIG. 3b**.

[1061] In a subscriber station originated RLP call **450**, the base station receives and decodes a first Service Request Message **452** indicating the subscriber station's ability to negotiate an initial RTT estimate during service negotiation or other proposed RLP parameters. Next, the RLP parameters indicated in the Service Request Message are evaluated **454** to determine whether any parameter changes should be negotiated. If so, the base station

sends a new set of proposed RLP parameters in a Service Response Message and sends it to the subscriber **456**.

[1062] If the RLP parameters evaluated at step **454** are acceptable to the base station, the base station sends a Service Connect Message **470**, indicating the RLP parameters to be used. The base station then decides **472**, based on the contents of the Service Connect Message, whether to perform a 3-way handshake. If so, the base station performs a 3-way handshake **474** and then begins sending user data. If no 3-way handshake is indicated by the Service Connect Message, then the base station proceeds directly from step **472** to sending user data **476**.

[1063] In a base station originated RLP call **460**, the base station begins service negotiation by sending a Service Request Message **462** to the subscriber station. This Service Request Message indicates that the base station supports specifying an initial RTT estimate during service negotiation. The base station then receives and decodes the Service Response Message received from the subscriber station **464**.

[1064] The RLP parameters indicated in the Service Response Message are evaluated **466** to determine whether any parameter changes should be negotiated. If so, the base station goes back to step **462** and sends a new set of proposed RLP parameters in a Service Request Message. Otherwise, the base station sends a Service Connect Message **470** and proceeds from that step as previously described.

[1065] **FIG. 5** is a flowchart of the steps used to update RTT estimates during an RLP session in accordance with an embodiment of the invention. In the case that the initial RTT estimate negotiated during service negotiation, it is advantageous for both sides to be able to adjust their RTT estimates according to measurements made during the call. This method uses information gathered during the transmission of NAK and retransmit frames to update the RTT estimate dynamically during an RLP call, resulting in an RTT update process that is integrated into the NAK process. For convenience, the procedure is described below from the viewpoint of a subscriber station in an RLP call. One skilled in the art will recognize that embodiments of the procedure may be performed by the subscriber station, the base station, or both without departing from the present invention.

[1066] The RTT estimate update procedure begins when the subscriber station detects a sequence number hole **502**. The subscriber station starts an RTT counter **504** to measure how long it takes to receive a retransmit frame for the one or more NAK frames to be sent. The subscriber station also initializes a NAK timer with the current RTT estimate and starts the NAK timer **506**. The subscriber station then sends the number of NAK frames **508** associated with the first round in the current NAK scheme.

[1067] Step **510** evaluates whether a corresponding retransmit frame is received before the NAK timer expires. If so, then the RTT counter is checked at step **520**. If the RTT counter is not running when the retransmit frame is received, then the RTT counter and NAK timer are stopped as necessary. If the RTT counter is still running when a retransmit frame is received, then the RTT estimate being used for the RLP call is updated **522** according to the new estimate. In an exemplary embodiment, the new RTT estimate is computed by performing a weighted average of the value of the old RTT estimate and the sum of the RTT timer and a predetermined guard time. One skilled in the art will appreciate that various other combining methods may be used without departing from the present invention. These other methods include replacing the RTT estimate with the sum of the value of the RTT timer and a guard time.

[1068] After updating the RTT estimate **522**, the RTT counter and NAK timer are stopped, and the RTT update process integrated into the NAK process ends **540**. If at step **520** the NAK timer is found to be not running, then the updating of RTT at step **522** is skipped, and the method proceeds directly from step **520** to step **524**.

[1069] If, at step **510**, the subscriber station discovers that the NAK timer has expired before a corresponding retransmit frame was received, then the subscriber station evaluates **530** how many NAK rounds have already passed without receiving a corresponding retransmit frame. The limit to the number of NAK rounds in the current NAK scheme was determined at the beginning of the call, either through the aforementioned NAK_ROUNDS_REV field, by the aforementioned predetermined default NAK scheme. If the number of NAK rounds passed is equal that limit, then the NAK limit has been reached. If the NAK limit has been reached, then no more NAK rounds are permitted for the corresponding hole, and the subscriber station proceeds to step **524**.

[1070] If, at step **530**, the NAK limit has not been reached, the subscriber station evaluates **532** whether the RTT estimate for the RLP call has ever been updated. If it has previously been updated, then the subscriber station stops the RTT counter **534** before starting the NAK timer again **506** and sending the next round of NAK frames **508**. Stopping the RTT counter before sending another round of NAK frames prevents retransmit frame ambiguity from causing inaccuracy in RTT estimates. For example, if a retransmit frame were received after a second round of NAK frames had been sent, the subscriber station would not know whether the retransmit frame corresponded to a NAK in the first round or the second round. Incorrectly matching such a retransmit frame to a later NAK round would lead to an incorrect RTT estimate.

[1071] Another problem occurs, however, with stopping the RTT counter after expiration of the first NAK timer. If, for some reason, the initial RTT estimate specified during service negotiation was artificially small, then the first NAK timer might expire before a first retransmit frame has the chance to reach the subscriber station. Under these circumstances, the erroneously small RTT estimate might never be updated, and could cause poor performance for the duration of the RLP call.

[1072] This problem is solved in the exemplary embodiment by allowing the RTT counter to continue running if the subscriber station determines **532** that the RTT estimate has not yet been updated. If the RTT estimate has not yet been updated, then step **534** is skipped, and the subscriber restarts the NAK timer **506** and sends the next round of NAK frames **508**. At worst, this may lead to an updated RTT estimate that is excessively long, but this is preferable over an RTT estimate that is too short. Correspondingly, in the preferred embodiment, step **522** gives the existing RTT estimate little or no weight in the weighted average the first time the RTT estimate is updated. In an alternate embodiment, the weighting of the existing RTT estimate in the first update varies based on the amount by which the first RTT estimate exceeds the existing RTT estimate and on the number of NAK rounds sent before receipt of a retransmit frame.

[1073] In an alternate embodiment, the decision at step **532** is based not on whether the RTT estimate has ever been updated, but on whether the hole corresponding to the expired NAK timer is the first hole detected in the RLP

session. If the hole was the first detected, then the RTT counter is not stopped before proceeding to step 506. If other holes had previously been detected, then the RTT counter is stopped 534 before proceeding to step 506.

[1074] FIG. 6 is a block diagram of an apparatus used to establish and use an RLP link through a CDMA wireless communication channel in accordance with an embodiment of the invention. For convenience, the apparatus is described below in terms of a subscriber station. One skilled in the art will recognize that the depicted configuration and its variations may be equally used in conjunction with a wireless base station without departing from the present invention.

[1075] The apparatus shown includes data interface 602 that may be connected an external input/output device, for example, a display terminal or handheld or laptop computer. Data interface 602 may be omitted if subscriber station 102 further includes an internal user interface, for example a keypad and a display. For example, subscriber station 102 might be a CDMA wireless personal data assistant (PDA) capable of exchanging data with the Internet and displaying it on a liquid crystal display (LCD).

[1076] Whether the raw user data is received through data interface 602 or from some other internal input/output interface, the data is manipulated as necessary by control processor 604. Control processor 604 performs the necessary formatting and protocol encapsulation to send the data over a wireless link. In the preferred embodiment, control processor 604 takes a byte stream received through data interface 602 and encapsulates it into RLP frames for transmission through CDMA modulation module 620. Control processor 604 also extracts data from RLP frames received through CDMA demodulation module 640 and provides the resultant byte stream to data interface 602. In addition to RLP frames, control processor 604 also performs service negotiation by transmitting and receiving Service Request, Service Response, Service Connect and other messages described above through CDMA modulation module 620 and CDMA demodulation module 640.

[1077] Control processor 604 is connected to and provides transmit frames to CDMA modulator module 620. In the preferred embodiment, control processor 604 provides the transmit frames to forward error correction (FEC) module 610, which encodes the frames based on an FEC code. FEC module

610 uses any of several forward error correction techniques, including turbo-coding, convolutional coding, or other form of soft decision or block coding. The resulting encoded frames are provided by FEC module **610** to interleaver **612**, which interleaves the data to provide time diversity into the transmitted signal. Interleaver **612** utilizes any of a number of interleaving techniques, such as block interleaving and bit reversal interleaving. The output of interleaver **612** is binary, and is then provided to Walsh spreader **614**, which spreads the signal using Walsh codes. After Walsh spreading, the output of Walsh spreader **612** is provided to pseudonoise (PN) spreader **616**, where it is spread using PN codes. The output of PN spreader **616** is then provided to transmitter **618**, where it is upconverted, amplified, and provided to diplexer **650**, and then transmitted through antenna **652**.

[**1078**] In the preferred embodiment, PN spreader **616** is a complex PN spreader that multiplies the complex output of Walsh spreader **614** by a complex PN code. In an alternate embodiment, PN spreader **616** multiplies the complex output of Walsh spreader **614** by a real (non-complex) PN code.

[**1079**] Signals received through antenna **652** pass through diplexer **650** and are then gain-controlled and downconverted in receiver **638**. From there, the signals are provided to CDMA demodulator module **640**, within which they are PN despread in PN despreader **636**, Walsh despread in Walsh despreader **634**, deinterleaved in deinterleaver **632** and FEC decoded in FEC decoder **630**. FEC decoder **630** provides the resultant received frames to control processor **604**.

[**1080**] In the preferred embodiment, PN despreader **636** is a complex PN despreader that multiplies the complex sample streams from receiver **638** by a complex PN code. In an alternate embodiment, PN despreader **638** multiplies the complex sample streams from receiver **638** by a real (non-complex) PN code. Deinterleaver **632** utilizes any of a number of deinterleaving techniques, such as block deinterleaving and bit reversal deinterleaving. FEC decoder **610** uses any of several forward error correction techniques, including turbo-coding, convolutional coding, or other form of soft decision or block coding.

[**1081**] The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to

other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

[1082] WHAT IS CLAIMED IS: